THE MASS OF THE ATMOSPHERE AND OF EACH OF ITS MORE IMPORTANT CONSTITUENTS.

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It is worth while, perhaps, to compute the approximate mass of the atmosphere and of each of its more important constituents. An exact calculation of these masses is not possible from the limited data we now have.[1] However, since but little gas of any kind extends beyond the 100-kilometer level, as we know from auroral and meteoric phenomena, it seems that both rotational and decrease-of-gravity effects must be small, and that the following computed minimum possible values are close to the exact values.

Total mass of the atmosphere.—The total mass A of the atmosphere, in grams, is given approximately by the continued product of the world average height of the mercurial barometer, in centimeters, at the actual surface of the earth; the density of mercury; and the area of the earth in square centimeters. These several values are: Average height of the barometer,[2] at normal gravity and 0° C., 73.7 cm.; density of mercury at 0° C., 13.5951; area of the earth, 51 by 10^{17} cm.[2] Hence

$$\begin{aligned} A &= 73.7\times 13.5951\times 51\times 10^{17} \text{ grams,}\\ &= 511\times 10^{16} \text{ kilograms.}\end{aligned}$$

Water vapor.—Assuming the distribution of humidity given by Arrhenius[3] to be substantially correct, and substituting his values in Hann's equation [4] for the total water vapor W in the atmosphere, it appears that, on the average, this vapor is the equivalent of a water layer 2.6 centimeters deep covering the entire earth. Hence, closely,

$$\begin{aligned} W &= 2.6\times 51\times 10^{17} \text{ grams,}\\ &= 1326\times 10^{13} \text{ kilograms.}\end{aligned}$$

Permanent constituents of the atmosphere.—To find the approximate amounts of the permanent gaseous constituents of the atmosphere, assume: (*a*) That the percentages of these several gases are constant, in the absence of water vapor, throughout the troposphere; (*b*) that in the stratosphere these gases are distributed each as though it alone were present. These assumptions are based on the facts that vertical convection, effective as a mixing agent, is active in the troposphere and absent in the stratosphere.

[1] Jeans, *The Dynamical Theory of Gases*, ch. xv; Woodward, *Bull. Amer. Math. Soc.*, 1900, 6: 143.
[2] Hann, *Lehrbuch der Meteorologie*, 3d edition, p. 182.
[3] *Phil. Mag.*, 1896, 41: 264; Hann, *Lehrbuch der Meteorologie*, 3d edition, p. 235.
[4] *Lehrbuch der Meteorologie*, 3d edition, p. 231.

Hence the total mass M of any one of the permanent gases of the atmosphere is given approximately by the equation

$$M = \underbrace{(1-k)(A-W)\,Vm'/m}_{\text{Troposphere.}} + \underbrace{k(A-W)\,V}_{\text{Stratosphere.}} \qquad (1)$$

in which k is the fraction of the whole atmosphere, exclusive of the water vapor, in the stratosphere; A the total mass of the atmosphere; W the total amount of water vapor in the atmosphere; V the volume per cent of the gas in question in dry air; m' the molecular weight of this gas; and m the virtual molecular weight of dry air.

According to Ramsay [5] and other good authorities, the volume percentages of the constituents of dry air, and their respective molecular weights, are:

Nitrogen	78.03	28.02
Oxygen	20.99	32.00
Argon	.94	39.88
Carbon dioxide	.03	44.00
Hydrogen	[6] .01	2.02
Neon	0.00123	20.0
Helium	.004	4.00
Krypton	.000005	82.9
Xenon	.000006	130.2
Dry air		[7] 28.97

Since the height of the troposphere varies with latitude, it follows that the percentage of the total air in the troposphere over any given place also is a function of latitude, as it is likewise of season and of weather conditions. However, from what is known of the upper air we may assume, as a fair approximation, that the world-wide average height of the barometer at the base of the stratosphere is 145 mm.

Substituting the proper values in (1) we have, for nitrogen,

$$M_n = \left(1-\frac{145}{735}\right)\left(511\times 10^{16}-1326\times 10^{13}\right)\left(\frac{78.03}{100}\right)\times\frac{28.02}{28.97} + \frac{145}{735}\left(511\times 10^{16}-1326\times 10^{13}\right)\left(\frac{78.03}{100}\right) = 38722986\times 10^{11}$$

kilograms.

Similarly for the other gases, varying, accordingly, the values of only V and m'.

Hence the total masses of the atmosphere and of its several constituents are, approximately—

	Kilograms.
Atmosphere	511×10^{16}
Nitrogen	38722986×10^{11}
Oxygen	11596239×10^{11}
Argon	623925×10^{11}
Water vapor	132600×10^{11}
Carbon dioxide	21658×10^{11}
Hydrogen	1291×10^{11}
Neon	471×10^{11}
Krypton	64×10^{11}
Helium	63×10^{11}
Xenon	11.6×10^{11}

[5] *Proc. Roy. Soc.*, 1908, 80: 599.
[6] This value is given in the *Recueil de Constants Physiques*, and is accepted by Hann. Some authorities, however, give much smaller values.
[7] Virtual, or weighted average, molecular weight.